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Development of multi-nutritional health biscuits from pearl millet processing

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Abstract
In this study lower shelf stability pearl millet has been targeted and gluten free biscuits were developed from 100 % pearl millet flour. Shelf life of pearl millet flour has been considerably increased through pearling of grains prior to milling for 10-12 min followed by storage in refrigeration which increased the shelf life of the flour from 7 to 28 days. Fat acidity and FFA increased from 4.5 to 78.9 mgKOH/100g and 2.3 to 39.6% respectively in case of unpearled grain compared to 2.3 to 36.6 mgKOH/100g and 1.2 to 18.4% in the pearled grain. Pearl millet based sweet and salted biscuits were nutritious, healthier, shelf stable as well as highly acceptable among the consumers. The proximate composition indicated high energy (448-488kcal), protein (7.8-8.5g), fat (16-22g), fibre (2.5g) per 100g. Iron (2.7 mg %), phosphorus (1600 mg %) and calcium (604 mg %) showed its richness in terms of micronutrients.

Keywords: pearl millet, pearling, storability, free fatty acid content, biscuits, value addition

Introduction
India is highest producer of pearl millet (*Pennisetum glaucum*) area and production wise. It is cultivated in 30 countries of Asia & Africa in over 26 million hectares. In India pearl millet occupies an area of 6.93 million hectares approximately (ICAR-AICRP) [14]. As per Directorate of Millets Development (2020) and Project Coordinator Review (2020) productivity of pearl millet has increased from 0.49 tonnes/ha in 1986-87 to 1.37 tonnes/ha in 2018-19 which is almost 2.7 times (ICAR-AICRP) [14].

Pearl Millet is a coarse cereal crop particularly grown in arid and semiarid regions of India especially in Gujarat, Haryana and Rajasthan which is conventionally known as '*Bajra'*. Its cultivation as well as consumption is second largest among all millets that are almost 25% of the total productivity of coarse cereals in the country (Amarender *et al*. 2013; Rai *et al*. 2008) [4, 25]. Pearl millet can replace some portions of a number of conventional crops like wheat, rice, maize etc due to its tolerance to extreme weather conditions such as high temperature, arid soil and low water availability. It is even superior to the conventional crops in energy, mineral and protein content (Sade 2009; Rai *et al*. 2008) [30, 25]. For lower income families pearl millet is a concentrated and cheapest source for energy and nutrients. Nutritional quality of pearl millet (Table 1) is better in comparison to other crops such as wheat, rice and sorghum and recently it is termed as 'super grain'. Pearl millet is healthier in the content of fat, energy and minerals and contains moderate amount of all amino acids except lysine (Gopalan *et al*. 1993) [11].

Wheat flour based products are made using wheat flours unique structural protein called gluten which owes then a characteristic functional property (Sapone *et al*., 2012) [31]. The same gluten is responsible for a life-long intolerance popularly known as celiac disorder which is being characterized as autoimmune enteropathy (Newinski, 2008) [22]. Generally individuals develop gluten susceptibility genetically which targets the gastrointestinal tract of the individual (Tye-Din & Anderson, 2008) [36]. After ingestion of gluten an immune mediated mechanism is triggered wherein inflammation of small intestinal mucosa is observed in gluten intolerant individuals that hamper the absorptive function of villi present in small intestine (Tye-Din & Anderson, 2008; Curiel *et al*., 2014) [36, 8]. Administration of gluten free diet for life is the only available treatment in current scenario for individuals with this autoimmune enteropathy (Naqash *et al* 2017) [21]. The highest prevalence of celiac disease is in Ireland and Finland and in places to which Europeans emigrated, notably North America and Australia. In these populations, celiac disease affects approximately 1 in 100 individuals. Complete elimination of gluten from the diet of an individual possesses a big challenge as large proportions of individuals around the world consume gluten based products as staple food.

Further these individuals will be deprived of calories and numerous vitamins, minerals and fibers which are supplied by gluten based products (Moroni *et al*., 2009; Yazynina *et al*. 2008) [18, 37]. Pearl millet is also a very good alternative for people intolerant to gluten. Therefore development of products using grains such as pearl millet it is very important to overcome challenges faced by gluten intolerant population.

Table 1: Nutritive Value of Pearl millet (NIN 2003; and Hulse *et al*. 1980) [23, 13]

Parameters	Content*
Energy (Kcal)	361
Protein (g)	11.6
Total minerals (g)	2.3
Fat (g)	5.0
Fibers (g)	1.2
Carbohydrates (g)	67.5
Calcium (mg)	42
Iron (mg)	8.0
Phosphorus (mg)	296
Carotene (µg)	132
Arginine (mg/g N)	300
Histidine (mg/g N)	140
Lysine (mg/g N)	190
Tryptophan (mg/g N)	110
Phenylalanine (mg/g N)	290
Tyrosine (mg/g N)	200
Hetheonine (mg/g N)	150
Cystein (mg/g N)	110
Theonine (mg/g N)	240
Leucine (mg/g N)	750
Isoleucine (mg/g N)	260
Valine (mg/g N)	330

Pearl millet has a number of potential health benefits owing to its chemical composition. Blood iron levels can be restored as it is a rich source of iron and zinc which raises the level of hemoglobin in blood (Sharma and Kapoor 1996) [32]. People suffering from constipation and obesity need to include more dietary fiber into their diet can supplement their meals with pearl millet which is rich in the fiber content (NIN 2003) [23]. Anticancerous activity of flavonoids and phenols which are majorly concentrated in the pericarp and testa of pearl millet (rich in phenolic compounds) can only received from the products that are prepared using whole pearl millet grain (Nambiar *et al*. 2011) [20]. Pearl millet based products can be consumed by diabetic patients as it has low levels of fructose and glucose (Oshodi *et al*. 1999) [24]. The study of Mani *et al*. (1993) [17] also reported that pearl millet has the low GI (Glycemic Index) (i.e. 55) which makes it highly suitable for diabetic population. Pearl millet can also be utilized in the prevention and treatment of a number of diseases such as arthritis, cardiovascular diseases, various types of cancers, alzheimers etc owing to its higher content of various omega 3-fatty acids [20]. Its higher content and quality of phytochemicals, and other nutrients have proven their role in improving the overall health and positive effect in different lifestyle associated disorders due to which it is receiving substantial recognition. However, its utilization is still low in developed countries due to unavailability of convenient forms and poor shelf stability (Gopalan *et al*. 1993; Rai *et al*. 2008) [11, 25]. The consumption of pearl millet has decreased also in India from 11.3 to 3.0kg (73.4%) in rural and 4.0 to 1.13kg (71.8%) in urban areas which is a matter of concern regarding its utilization.

Pearl millet is susceptible to spoilage and development of off flavor on storage longer than 6-8 days. Some biochemical changes like lipolysis and proteolytic activities might be an attributing factor. Rapid development of rancidity and bitterness in the flour has been a major problem in the acceptability and utilization of the pearl millet flour. In pearl millet the quality of flour require to be improved for its better acceptability and longer shelf life. Due to high fat content its storability is poor, particularly of its flour. Pearling of the pearl millet grain can improve its palatability as well as shelf life.

Pearl millet grains are rich in both membrane lipids and essential fatty acids which accounts for its 5.5% fat content (free and bound lipids). Germ, pericarp and aleurone layer are the major sites for holding this fat content of pearl millet. Its fat is rich in palmitic and stearic acids and deficient in oleic acid content (Rooney 1978) [28]. This high lipid content becomes a prime reason for lower shelf stability of the flour as the seeds are also rich in lipase enzyme. During storage, free fatty acids (FFA) in the lipids of theses grains especially the unsaturated FFA hydrolyzed in the presence of lipase to produce aldehydes and ketones which are the prime compounds responsible for bitter taste and foul smell. In order to maintain the acceptability of the pearl millet even after storage it is suggested that grains should be dried to a minimum moisture content prior storage so as to slow down the activity of lipase enzyme. Many other processes are also suggested by different researchers among which pearling is a very common and effective method for shelf life increment of pearl millet flour.

Material and Methods

Pearl millet variety HHB-67 was taken for experiments. Grain pearler (CIAE, Bhopal) of dimension (166×500×1000 mm) and 90 kg/h at 1000 rpm with a motor capacity of 7.5 hp is used to peel and clear out the branny layers of the pearl millet grain through the application of abrasion and friction, which produces flour with long storability. In the present study pearling was done for 10 to 12 minutes to remove the outer bran layer from the pearl millet grain in the grain pearler. The shelf life of pearled flour prepared from the grains was analyzed consecutively after 7, 14, 14 and 28 days of storage in ambient and refrigerated condition.

The different unit operation involved in making pearled pearl millet based baked product (Biscuit) with 100 % pearled pearl millet flour are shown in flow diagram (Fig. 1). Composition of biscuits was standardized and the core ingredients for making sweet biscuit was Pearl millet flour 1 kg, bakery shortening 400 g, sugar 400g, baking powder 10g, and sesame seeds. In salted biscuits aniseeds (*jeera*) 20 g was used in place of sesame seeds to give spicy flavor. Dough kneader with capacity of 1.5 hp of capacity 60 kg/h was used to knead the biscuit dough. Double deck baking oven (VSG equipments, Jodhpur) was used for baking at 180°C for 45 minutes. Biscuits were cooled and packaged in plastic boxes.

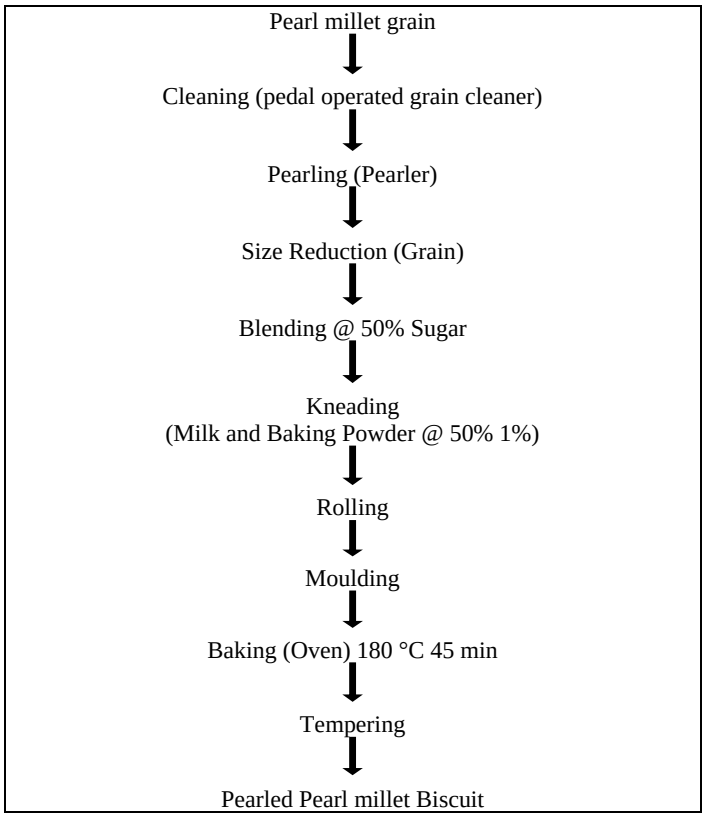

Fig 1: Process flow chart for development of biscuits from pearl millet flour

Changes in the lipid of pearled pearl millet flour during storage were analyzed for fat acidity, FFA and peroxide value (PV) by AACC titrimetric method (1984) [2], AACC International (2000) [1], AOACS.Cd8b-90 (2011) [6] respectively.

The proximate composition of pearl millet biscuits developed under the study was analyzed using standard methods. The moisture, protein, fat, fiber, ash & FFA (as oleic acid) were analyzed by the method of AOAC (2019) [5]. The energy content was analyzed by the method given by James *et al*. (2007) [15] and the carbohydrate content was analyzed by the method of Sadasivan and Manickan (2005) [29]. Different minerals such as Ca, Fe & P were analyzed by ICP-OES mineral analysis as per the method of AOAC (2019) [5].

Results and Discussion

Pearling is the unit operation involving the application of frictional and abrasive forces for the effective separation of bran layer from the outer seed coat of the cereal grain prior to milling. By adjusting the open space between the abrasive surfaces and the duration of the pearling treatment degree of bran removal can be easily regulated. The entire bran layer i.e. 18% of the grain is removed during this abrasive operation. In this treatment only the bran layer is removed while keeping the other nutritious layers, such as the aleurone intact to the kernels under treatment. This pre-treatment will not only extend the shelf stability of the milled and processed products but also has a potential to provide superior quality flour with improved milling outputs (Mousia *et al*. 2004) [19].

Table 2: Effect of pearling on changes in lipids of pearled pearl millet flour during storage

Treatment	No. of days			
	7	14	21	28
Fat acidity (mg KOH/100g meal)				
Unpearled (Control)	4.5	15.2	40.1	78.9
Pearled	2.3	6.3	21.7	36.6
Free fatty acid (%)				
Unpearled (Control)	2.3	7.6	20.1	39.6
Pearled	1.2	3.2	10.9	18.4
Peroxide value (meq/kg oil)				
Unpearled (control)	38.6	90.2	10.9	57.5
Pearled	49.4	36.4	33.0	36.1

In the present study the flour from pearled as well as unpearled grain was stored for 30 days. The flour was analyzed periodically (7, 14, 21 & 28 days) for shelf life by chemical methods. Fat acidity and FFA increased from 4.5 to 78.9 mgKOH/100g and 2.3 to 39.6% respectively in case of unpearled grain compared to 2.3 to 36.6 mgKOH/100g and 1.2 to 18.4% in the pearled grain. PV which is an indicative of oxidative changes in lipids, steadily increased in storage, reached a maximum, and then gradually declined. The result of the study indicated that the shelf life of pearl millet flour derived from pearled grain can be appreciably improved by pearling the grain. The effect was also studied for lipids content of pearled millet flour (T1: Pearled, T2: Unpearled) during storage at ambient condition i.e. 41°C & 60% RH and compared with those kept under refrigerated conditions. Fat acidity, FFA and PV were analyzed (Table 3).

Considerable reduction in the fatty acid and free fatty acid content of pearl millet after pearling (pre-milling treatment) was seen which extended the shelf life of the pearl millet flour by keeping its sensory attributes intact. Similar results was also reported by Tiwari *et al*. (2014)[34] in his study on effect of various pre-milling treatments like pearling, fermentation and heat treatment on the shelf stability of pearl millet flour. According to the study by Mousia *et al*. (2004) [19] stated that microbial contamination is reduced by 90% on the removal of approximately 4% of the bran layer.

Table 3: Effect of temperature on changes in lipids of pearled pearl millet flour during storage

Days	Ambient/ Refrigerated condition	Fat acidity or Acid value Mg KOH/kg		FFA %		PV Meq/kg	
		T1	T2	T1	T2	T1	T2
0	Ambient	4.62	11.09	2.32	5.57	16.39	16.39
10	Ambient	7.25	20.93	3.64	10.52	27.52	16.24
10	Refrigerated	4.62	11.09	2.06	5.57	33.06	25.33
20	Ambient	13.87	40.7	6.44	20.4	20.95	11.06
20	Refrigerated	4.62	11.09	2.09	5.57	33.44	21.06

T1: Pearled, T2: Unpearled

Results of storage in ambient and refrigerated condition indicated that pearl millet flour has deteriorated much less compared to the flour prepared from unpearled grain under ambient conditions in 20 days. However, there is practically no change in the quality of flour kept under refrigerated conditions in both cases. The observations about fat acidity and FFA compositions in the studied samples suggested that pearling of grain followed by refrigeration can be applied to control the severe problem of rancidity and off-flavor during storage of pearl millet flour.

Efforts are made to develop pearl millet based product with 100% pearled pearl millet flour of locally produced variety HHB-67, which can serve as breakfast food or snack. Among food uses, pearl millet can be consumed in various forms such as breakfast cereals, snack products (puffed/popped), extruded products, ready to eat products, baked products, malted food/weaning foods for infants and health foods for people with special needs like diabetic, gluten intolerance, obesity, constipation etc.

Biscuit is a sweet and unleavened crispy bakery product which is popular worldwide. These are generally prepared by combining sugar and shortening with refined wheat flour. It is a suitable bakery item for fortification with proteins and other nutrients which will improve its nutritional quality. It is highly popular among all age groups as a snack with better taste and longer shelf life. Due to increasing demand for various healthy and natural products a number of trials are being carried-out to develop biscuits with improve functionality and nutritive value (Gayas *et al*. 2012; Tyagi *et al*. 2007) [10, 35].

Table 4: Proximate composition of different types of biscuits prepared using pearl millet flour

S. No.	Samples	Proximate Composition										Reference
		Energy Value (Kcal)	Moisture (%)	Carbohydrates (%)	Fat (%)	Protein (%)	Ash (%)	Fiber (%)	Ca (Mg)	Fe (Mg)	P (Mg)	
1.	PB[a] sweet (PM[b] 100%)	448.21	5.32	65.29	16.97	8.58	1.28	2.56	604	27	1900	#
2.	PB[a] salted (PM[b] 100%)	488.83	0.99	64.78	22.03	7.87	1.81	2.53	604	27	1900	#
3.	PB[a] (PM[b] 100%)	447.84	5.77	64.48	18.77	8.01	1.23	1.75	-	-	-	Adebiyi *et al*. (2017) [3]
4.	FB[c] (PM[b] 100%)	452.05	5.23	67.82	15.62	8.79	0.76	1.77	-	-	-	Adebiyi *et al*. (2017) [3]
5.	MB[d] (PM[b] 100%)	458.67	5.09	65.19	16.95	9.84	1.13	1.80	-	-	-	Adebiyi *et al*. (2017) [3]
6.	PB[a] (WF[e]:PM[b]:: 50:50)	1398	-	75.97	43.88	10.92	-	11.50	29.14	5.26	-	Singh and Nain (2020) [33]
7.	PB[a] (CF[f]:PM[b]:: 50:50)	1416	-	75.25	45.36	16.25	-	13.32	41.33	6.53	-	Singh and Nain (2020) [33]
8.	PB[a] (RF[g]:PM[b]:: 50:50)	466.03	3.06	-	16.07	7.3	1.59	-	-	-	-	Rai *et al*. (2014) [26]
9.	PB[a] (SF[h]:PM[b]:: 50:50)	458.88	3.01	-	19.17	7.4	1.60	-	-	-	-	Rai *et al*. (2014) [26]
10.	PB[a] (PM[b] 100% K[i] variety)	374	10.8	75	4.4	8.5	1.3	-	45.6	4.06	310.5	Florence *et al*. (2014) [9]
11.	PB[a] (PM[b] 100% MRB[j] variety)	382	9.5	75	5.0	10.1	1.3	-	48.6	5.83	270.0	Florence *et al*. (2014) [9]

a- Pearl Millet Biscuits, b – Pearl Millet Flour, c- Fermented Pearl Millet Biscuits, d- Malted Pearl Millet Biscuits, e- Wheat Flour, f- Chickpea Flour, g- Rice Flour, h- Sorghum Flour, i- Kalukombu, j- Maharashtra Rabi Pearl, # developed in the present study

The proximate composition showed the nutritive value of sweet and salted pearl millet biscuit (PB) (PB Sweet; PB salted with 100 % pearl millet flour) developed under the present study. Different types of pearl millet biscuits are also developed under various studies for which the comparative values with the product developed in this study are presented in Table 4. Calorific value (kcal) of all 100% pearl millet biscuits did not show much variation except for salted pearl millet biscuits prepared under this study which had a calorific value of 488.83 kcal which is significantly higher. According to study of Rai *et al*. (2014) [26] biscuits containing 50% pearl millet and 50% rice flour/sorghum flour had calorific value almost same as 100% pearl millet biscuits. Biscuits prepared using two varieties (Kalukombu and Maharashtra Rabi) show significant reduction in the calorific value. In another study biscuits containing 50% wheat flour and chickpea flour along with pearl millet flour showed a drastic increase in the calorific value of 1328 kcal and 1416 kcal respectively but very low fat content of 4.4% and 5.0% respectively (Florence *et al*. 2014) [9]. In the study of Singh and Nain (2020) [33] protein content of the pearl millet biscuits was observed to be double when 50% pearl millet flour was substituted with chickpea flour which may be due to the addition of pulse flour. Fiber content of pearl millet cookies was also observed to increase after the addition of wheat flour and chickpea flour (Table 4).

In the study by Rai *et al*. (2014) [26] similar gluten free cookies were prepared by combining four alternative flours (rice, sorghum, maize and pearl millet). Various physiochemical, organoleptic and functional properties of the cookies were compared with wheat flour cookies (control). Among all combinations wheat flour cookies had the highest yield. Highest and lowest spread ratio was observed in rice- maize and rice-sorghum cookies respectively. Calorific value and proximate composition was highest in pearl millet-sorghum cookies. Order of organoleptic acceptability was as follow pearl millet-sorghum > rice-sorghum > maize-sorghum > rice-maize > maize-pearl millet > rice-pearl millet > wheat. Nutritional value as well as acceptability was higher for all types of cookies except of the wheat flour cookies Rai *et al*. (2014) [26].

In another study by Florence *et al*. (2014) [9] likelihood of substituting conventionally used refined wheat flour in the preparation of cookies with two distinct varieties of pearl millet (K and MRB) was determined. On proximate evaluation of the prepared cookies of both the varieties revealed that cookies prepared out of pearl millet are more nutritious in terms of proteins and minerals such as iron, phosphorus and calcium. Sensory profile which was evaluated using 'Quantitative Descriptive Analysis' (QDA) method reported that pearl millet cookies had a better sensory characteristics than the conventional one (wheat flour cookies). Further, the palatability of pearl millet cookies was enhanced after the perception of their crispy and crumby texture [9].

Singh and Nai (2020) [33] in its study prepared biscuits using 100% wheat flour, wheat and pearl millet flour in ratio of 50:50 and pearl millet and chickpea flour in ratio of 50:50. These biscuits were analyzed for their proximate composition and sensory acceptability. Biscuits prepared using pearl millet-chickpea flour were found to be more acceptable as well as higher in content of carbohydrates, proteins, fat, dietary fibre and mineral (Ca and Fe).

Recent significant work by Adebiyi *et al*. (2017) [3] prepared biscuits using native, malted and fermented pearl millet flour and analyzed three of the samples for their nutritional quality. The proximate composition of biscuits prepared by Adebiyi *et al*. (2017) [3] did not reported much variation in comparison with biscuits prepared from untreated and pearled pearl millet flour in his study except for protein content which was slightly higher in fermented and malted flour biscuits. Similarly ash and fat content of biscuits had decreased in fermented flour biscuits. It can be concluded that pre-treatments like fermentation and malting showed slight improvement in protein content (Adebiyi *et al*. 2017) [3].

Pearl millet biscuits contain high resistant starch and fibre content mostly of insoluble nature. As per study of Boora & Kapoor (1985) [7] and Kapoor & Kapoor (1990) [16] fresh pearl millet flour has a Protein efficiency ratio of 1.83 to 1.82 and 1.74 respectively. High PER of fresh pearl millet indicates that PER for pearl millet biscuits will also be higher. Therefore, these biscuits can be an ideal food supplement or snack food item with functional health benefits. Pearl millet starch is high in maltose and D- ribose while glucose is low thus having lower glycemic index and highly suitable for diabetics. Pearl millet biscuits are gluten free hence they are suitable for celiac disease patients. All these functionalities of pearl millet are the reason for which it needs to be incorporated into various processed products which is healthy as well as economical (Rasane *et al*. 2015) [27].

Conclusion

The presence of various phytochemicals, dietary fibers, starch components, functional proteins and unsaturated fatty acids are the prime reason for tremendous increase in the popularity for consumption of pearl millet (Rasane *et al*. 2015) [27]. It has a well balanced composition of good quality proteins, lipids mainly unsaturated and omega fatty acids, vitamins, minerals and phytochemicals (Head *et al*. 2010) [12]. Pearl millets being rich in a number of minerals (iron, phosphorus, zinc) etc and other functional components has a lot of potential for utilization in the development of a number of snack products. It's inclusion into diet indicates cure and prevention of various health issues related to heart, bone, gastrointestinal tract etc. One of the major drawbacks of pearl millet grain based product is the lower shelf stability which can be resolved considerably through pearling of these grains prior to milling followed by refrigerated storage as indicated in the study. It can become a strong alternative for various other highly acceptable and otherwise unhealthy snacks/junk foods popular in the markets. Biscuits are one of the most convenient forms to deliver nutrients and abundant health benefits of pearl millet for people of all age groups. Also pearl millet based biscuits found economical, shelf stable as well as highly acceptable among the consumers. Pearl millet biscuits can act as a vehicle for the delivery of functional and phytochemical compounds of pearl millet in areas, where it is not conventionally eaten. Salted and sweet biscuits developed from 100% pearl millet flour in this study have high energy and protein density and rich in minerals particularly, iron, calcium, phosphorus and zinc. Pearl millet commercialization will also provide healthy alternative to consumers with special needs like diabetics, celiac disease patients, pregnant and lactating mothers, children and adolescents, and people with dementia. These kinds of products can also be included in ICDS (Integrated Child Development Services) and other developmental schemes for malnourished children and women which may help to overcome the (Protein energy malnourishment and anemia) through food chain occurring largely in the developing countries.

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